

A COMPARISON OF FORWARD AND BACKWARD PROCEDURES FOR THE ACQUISITION OF RESPONSE CHAINS IN HUMANS

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Ten university students each learned four separate six-link response chains, two forward and two backward. All 10 subjects made fewer errors in the forward procedure. It was concluded that the forward procedure is superior because each link of the response chain is acquired by direct reinforcement.

Key words: response chaining, forward and backward chaining, acquisition, discriminative stimulus hypothesis, key press, humans

The importance of behavior chains was emphasized by Skinner in *The Behavior of Organisms*: "The use of a chain cannot be avoided in dealing with operant behavior because the very act of reinforcement implies it" (1938, p. 54). More recently, other authors have also deemed this an important topic, and have indicated that it is difficult and inefficient to train a response chain by the forward method. "To construct this chain of performances, we actually begin backwards, reinforcing the final performance first" (Ferster and Perrott, 1968, p. 176). These authors ask the student to: "Say why it is *necessary* to build a chain starting at the final performance" (p. 181, *italics added*). Others have held similar views: "Strengthen the members that occur nearest primary reinforcement first; that is build the chain from back to front" (Millenson, 1967, p. 260); "... the guiding principles are to establish the chain from its final member first and to reinforce additional preceding patterns of behaviour by giving the discriminative stimulus which controls the next pattern of behaviour in the chain" (Blackman, 1974, p. 97). "The important rule in establishing chains is to start with the last response—the one that is rewarded with primary reinforcement" (Rachlin, 1976, p. 121).

But the evidence supporting these views has been sparse. In addition, abundant anecdotal evidence suggests that humans often learn behavior chains by the forward method. For ex-

ample, verbal chains are often acquired by learning the first response first, not last. Teachers do not teach the alphabet Z, YZ, XYZ, WXYZ, *etc.*, but rather A, AB, ABC, *etc.* There is little systematic experimental evidence relating to the relative effectiveness of the forward and backward procedures for the acquisition of response chains. The present study was designed to clarify that question.

METHOD

Subjects

Ten first-year psychology students at University College London, who had not yet studied response chaining in their course, served as subjects.

Apparatus

The response console consisted of six response keys, a three-digit light-emitting diode counter, red and green indicator lamps, and a speaker for presenting tones (Figure 1). Each response key was pivoted on a hinge and when pressed, actuated a microswitch, which was obscured by the front panel. Behind the clear plastic (Plexiglas) keys were hexadecimal displays, which could be illuminated with the symbols A, B, C, D, E, F, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 (Hewlett-Packard 5082). All stimulus programming and response recording were controlled by a computer operating on-line.

Procedure

The subject was seated on a stool in front of the console and the experimenter read the following instructions:

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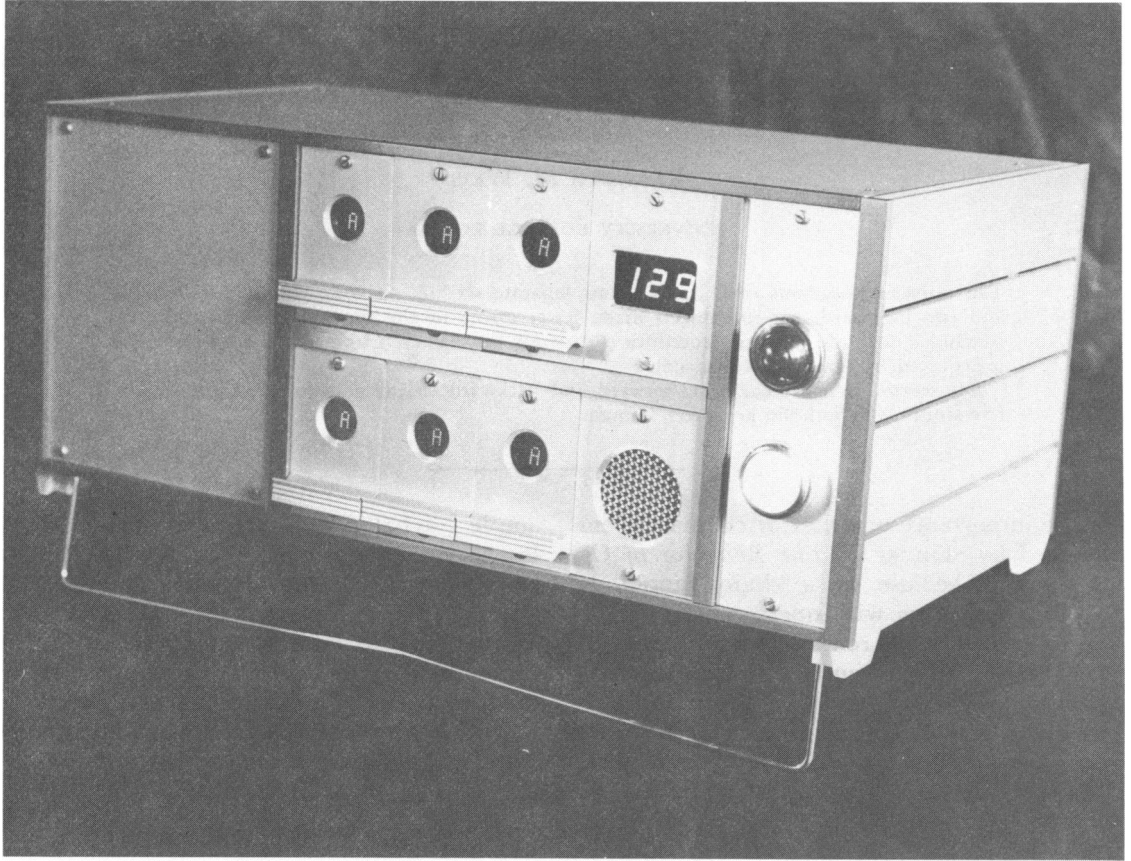


Fig. 1. The console used in the experiment, showing the response keys and displays, three-digit counter, speaker grill, red and green lights.

This is an experiment to study the learning of sequences of responses. You will be asked to learn four separate sequences, each consisting of six responses. You must learn each response sequence gradually. First, you must make just one response without any errors before getting five points. Then, you will have to make two responses without any errors before getting five points, then three responses without any errors before getting five points, and so forth until you have built up to six responses without any errors which are required before you get five points. Behind each button there will be a letter or number or symbol. At any one time, all six symbols will be the same. Each time you make a correct response the symbols will change. Each symbol goes with one particular button which is the correct one at that time. For example, "A" may be the

top left button, "B" may be the top center button, and so forth. Remembering which buttons go with which symbols may help you remember the sequence of correct button pushes. If you make a correct response a tone will sound and the symbols will change. At the end of the sequence you will get five points if you have done it without any errors. If you make an error, you will lose one point and a buzzer will sound. After ten sequences without an error, the symbols will go off for about ten seconds and then a new sequence will be started. Each of the four sequences are completely separate from the others. Press the buttons only when the green light is on. At the end of the fourth sequence, the experiment is over. You will be paid one penny for each three points you have earned and you begin the experiment with 50 points.

After reading the instructions, the experimenter demonstrated the console. A three-link response chain consisting of "1" -upper left, "2" -upper center, "C" -lower left, was followed by five points on the three-digit counter accompanied by five brief tones (700 Hz). Errors were also demonstrated by pressing the "wrong" response key, which resulted in a buzzer (60 Hz) for 0.5 sec and a loss of one point on the three-digit counter. When the symbols changed, the displays were blank for 640 msec, the green light went off, and the red light came on. The subject was then asked if he or she understood the task. If the response was negative, the three-link chain was demonstrated again. When asked, all subjects indicated that they understood what was required at this point.

The subjects were equally divided into two groups: (1) forward-chain-first (Subjects 1 to 5) and (2) backward-chain-first (Subjects 6 to 10). The forward-chain-first group were required to learn the four six-link chains in the order forward, backward, forward, backward. The backward-chain-first group learned the chains in the order backward, forward, backward, forward. Only the type of procedure for learning the chains was reversed; the order of the actual chains to be learned was the same for each subject (see Table 1).

RESULTS

Acquisition was judged by counting the number of true errors made. A true error is an error made on trials subsequent to the one in which a link was introduced. As it is a matter

of chance how many errors a subject makes before discovering which response button is correct, the total number of errors is not a meaningful measure. But after the initial discovery trial, responses on an incorrect key were defined as true errors (as distinguished from the errors mentioned in the instructions, which included all incorrect responses).

Figure 2 illustrates the number of errors made by each subject in each of the two conditions. Subjects 1 to 5 were in the group that learned the forward chain first, Subjects 6 to 10 in the group that learned the backward chain first. Every subject made more errors in learning the backward chains. This was true regardless of which procedure was first and regardless of the overall ability of the subject, as reflected by the overall error rate. Table 2 shows the number of errors made by each subject in each of the four chains learned. No individual subject learned any chain backward with fewer errors than they learned the chains with the forward procedure. In other words, there were no negative instances.

When interviewed after the experiment, most subjects reported that they used the stimuli to tell them where they were in the response chain and they associated the stimulus symbols with the keys. Two subjects reported that they were more dependent on a series of response button positions and paid little at-

Table 1
Sequence Stimuli and Responses

Chain		R6	R5	R4	R3	R2	R1 ... S+
I	Stimulus	2	7	9	5	C	3
	Response	LR	UL	UR	LC	UC	LL
II	Stimulus	4	A	F	6	0	D
	Response	UC	LR	LL	LC	UR	UL
III	Stimulus	9	1	8	D	3	B
	Response	LC	UL	LL	UC	LR	UR
IV	Stimulus	A	8	3	5	E	0
	Response	LC	UL	UC	LR	LL	UR

Key:

UC = Upper Center LC = Lower Center
UL = Upper Left LL = Lower Left
UR = Upper Right LR = Lower Right

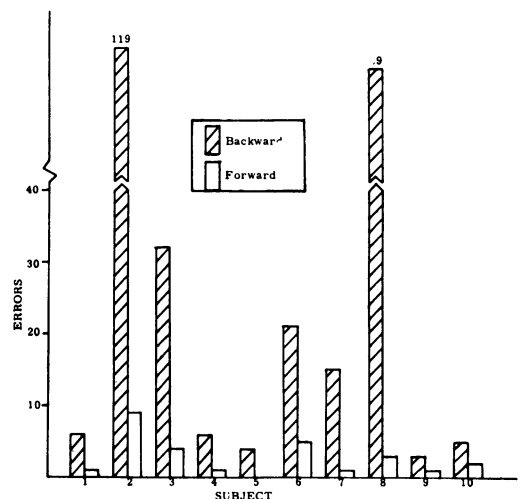


Fig. 2. The number of errors made by each subject in the forward and backward procedures. Subjects 1 to 5 were in the forward-chain-first group. Subjects 6 to 10 were in the backward-chain-first group.

Table 2
Number of Errors

Subject	Errors	
	Backward	Forward
1	3, 3	1, 0
2	114, 5	5, 4
3	24, 8	4, 0
4	1, 5	1, 0
5	2, 2	0, 0
6	9, 12	5, 0
7	1, 14	0, 1
8	36, 43	3, 0
9	2, 1	0, 1
10	3, 2	1, 1

tention to the symbols. Two subjects who made many errors, Subjects 2 and 8, reported that "my mind just wandered" and "I lost my concentration". About a third of the subjects noticed the difference in the procedure when it changed from forward to backward or *vice versa*.

DISCUSSION

Clear superiority of the forward-chain method was demonstrated in the acquisition of a six-link response chain. Keehn (1967) also found that forward was superior to backward chaining with negative reinforcement, but concluded that because of the unusual circumstances of his experiment, he could not say anything about the relative merits of the two procedures.

Perhaps backward chaining has been thought to be preferred because it offers an explanation of how links that are not directly reinforced can be maintained. In a behavior chain R3-R2-R1-S+, it can be assumed that R3 is reinforced by the presentation of the discriminative stimulus for R2, and R2 is in turn reinforced by the presentation of the discriminative stimulus for R1. This interpretation predicts that if R2 were extinguished, R3 would also be weakened because it is maintained by the discriminative stimulus for R2. Fantino (1965) demonstrated that responding may be maintained even when the stimulus in the next link no longer controls responding. He concluded that this supported the idea that "although the stimulus was no longer a discriminative stimulus for responding in its presence, it continued to reinforce responding

to obtain it" (p. 409). Although it may yet be an open question as to what is reinforcing the response in question, the discriminative stimulus hypothesis has been challenged by several research workers (e.g., Hendry, 1969). It may be that it is simply one possible account of how backward chains might be learned.

Another interpretation can explain the superior acquisition of forward chains. The difference between the backward and forward procedure is illustrated in a three-link chain in Figure 3. What is apparent in the backward chain is that the only response that is contiguous with the reinforcer is the final response, R1. However, in the forward-chain procedure, each response is acquired by being directly reinforced, i.e., each response has a trial on which it is contiguous with the reinforcer, S+. This contiguity, even for only a single trial, may be powerful enough to yield the superiority found in the present study. It is possible that the reason why the backward procedure was poorer is that to establish the discriminative stimulus for R1 requires considerable exposure and that in the present experiment the links were added too quickly. However, this does not account for the superiority of the forward method. What would be useful is a study of the process of acquisition of the reinforcing property of a discriminative stimulus. The present result might be summarized by the principle: the stronger the reinforcer used to establish a response, the stronger the response tendency. This is just a natural extension of the law of effect. Many studies have substantiated the idea that magnitude of reinforcement is positively related to the acquisition of responses (Mackintosh, 1974). The present results, when viewed in the light of the fact that each response in a for-

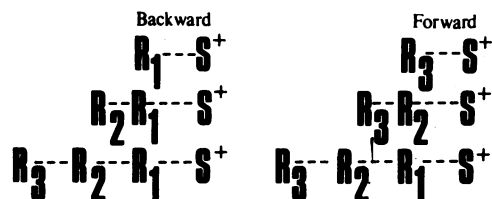


Fig. 3. Acquisition of a three-link response chain by forward and backward procedures. Note that in the backward procedure, only R1 is contiguous with S+, whereas in the forward procedure, each response is contiguous with S+.

ward-chain procedure is directly reinforced, whereas only the terminal response is directly reinforced in a backward chain, lead to the prediction that forward chaining would be superior for the acquisition of a response chain.

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